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ARTIFICIAL SODIUM CLOUDS. WIND SPEED, TURBULENCE AND DENSITY OF THE HIGH ATMOSPHERE

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Two artificial clouds of sodium were emitted in the high atmosphere by means of Veronica rockets. Observation of the deformations of these clouds permits the study of the wind speed, turbulence and density of the high atmosphere.

Two experiments in projecting sodium into the atmosphere by means of Veronica rockets took place in Algeria, one at twilight 10 March 1959 where the rocket attained an altitude of 127 km, and the second at dawn 12 March where the rocket reached an altitude of 180 km. The sodium was projected in a continuous manner according to the current method (see H.D. Edwards, J.F. Bedinger and E.R. Manring, "Emission from a Sodium Cloud Artificially Produced by Means of a Rocket" in The Airglow and Aurorae: a symposium held at Belfast in September 1955). A visible cloud caused by the optical resonance of the sodium atoms excited by solar light was formed at the ascent and descent above an altitude of 90 km. The meteor lasted about thirty minutes and disappeared because of the light conditions.

The group from the physics laboratory of l'Ecole Normale Superieure (Upper Normal School) had proposed the following measurements as a function of the altitude: first, wind speed and density by observation of the deformations of the cloud in time; second, temperature and reactivity with the sodium by interferometer measurements. The principle of the experiments and some preliminary results of analysis for the measurements of the first group are presented in this article.

1. Three observation posts, α, β, γ were placed at the vertices of a roughly equilateral triangle with 110 km per side. The fourth post, α', was located 8.65 km from the post . A camera O.M.E.R.A. (focal distance, 20 cm; lens opening, f2; field, 32°; film, Tri X Kodak) was established at each of the observation posts.

Measurement of wind speeds.

Altitude (km)	98.2	105.6	107.9	117
Wind speed (km/hour)	80	200	95	220
Wind direction	NW-SE	S-N	N-S	SE-NW

Voice synchronization signals given by one of the posts permitted the four posts to take simultaneous photographs (precision, one fifth of a second), at an average of three per minute with exposure times varying from 1 to 30 seconds. The stars which were visible on the most exposed plates permitted the determination of the viewing direction. The best method of studying the complicated geometry of the cloud seemed to us to be stereoscopic photogrammetry, a process analagous to the restoration of a relief from two aerial photographs. This method was suggested to us by l'Institut Geographique National (National Geographic Institute) which participated in scrutiny of the data with the aid of a Poivilliers apparatus while utilizing only the plates taken from the short base $\alpha\alpha'$. The two clouds had a very different appearance. In the experiment of 10 March, the cloud below 100 km resembled a cumulus cloud with streamers whose diameter was on the order of 500 m to 1 km. Above 102 km, the cloud had a sleek appearance. Table I indicates the speed and direction of the wind as a function of the altitude. Thus two distinct regions appeared, one unstable where the wind is feeble, and the other stable where the shearings are important. The boundary of the two zones, which is in the vicinity of the altitude of emission of the ray 5,577 A of O [I] in the sky at night, is perhaps connected with the inversion of the temperature gradient at a slightly lower altitude.

In the experiment of 12 March, on the other hand, the form of the cloud showed neither turbulence below 100km nor shearing above 100 km. Other experiments will be necessary to decide whether the hour of launching (morning or evening) is responsible for these differences.

Figure 1. Plate of the first cloud.
Figure 2. Plate of the second cloud.

2. Successive photographs show that the width of the trail increases with time because of the diffusion of the sodium atoms in the atmosphere. This diffusion occurs more rapidly when the density of the atmosphere is lower. Hence the study of the width of the cloud permits the determination of the coefficient of diffusion D of sodium and consequently the density.

After a first rapid phase of expansion during which the sodium atoms reach thermal equilibrium with the atmosphere, we assume that the distribution $n(r)$ of the sodium atoms in a horizontal plane is a gaussian of small width L_o: e^{-r^2/L_o^2}. The theory of diffusion shows that at a later moment, the distribution of the sodium atoms is always a gaussian and that the curve representing L^2 as a function of time is a straight line with slope 4D which permits the determination of D. The difficulty consists in measuring and defining the width L since, because of the absorption and multiple diffusion of the resonance light in the cloud, the intensity of the light emitted is not directly proportional to the density of the atoms. In a first approximation, we neglected this effect and defined L at a certain altitude as the distance from the points of the cloud where the intensity is reduced to 1/e of the intensity to the point which is most brilliant at this altitude.

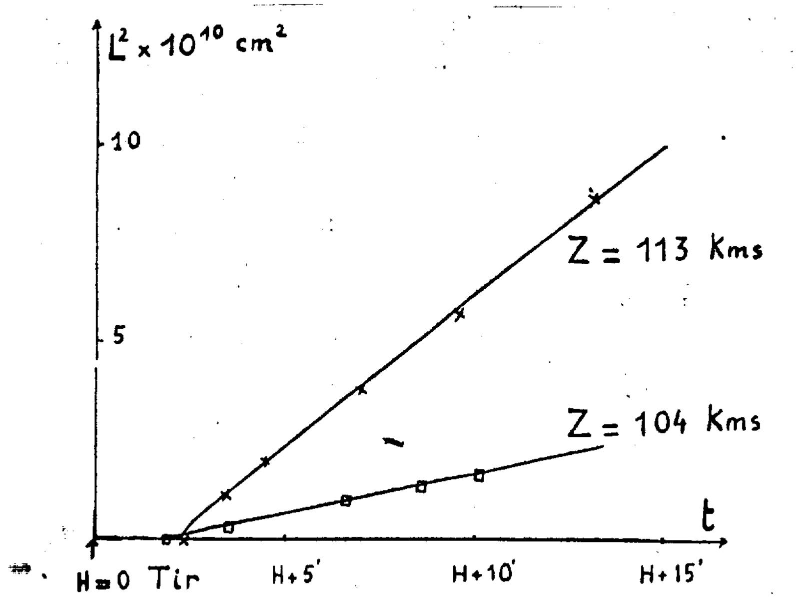

Figure 3. Measurement of D

The results of these measurements for points at altitudes 104 and 113 km is given on figure 3. The ratio of the two slopes corresponds to the ratio of the two densities and is equal to 3.6, an excellent agreement with the measurements of density by other methods (see H.E. lagow, R. Horovitz and J. Ainsworth, "Rocket measurements of the Arctic Upper Atmosphere," I.G.Y. Rocket Report Series , No 1, 30 July 1958).

The effectual collision section, derived from these values of D, is

$$\sigma^2 = 1.2 \times 10^{-16} \text{ cm}^2,$$

a value which is not unreasonable.

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